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Water Quality Study of the Lower Spanish River

July 1972

Environment Ontario

WATER QUALITY STUDY

OF THE

LOWER SPANISH RIVER

JULY 1972

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INTRODUCTION

This report presents the findings of investigations of the effects of wastewater discharges from the kraft mill of Eddy Forest Products Limited and the Town of Espanola primary sewage treatment plant on the Lower Spanish River.

Most of the water quality information contained in the report was obtained from an intensive investigation of the area during August 1971 by the Water Quality Surveys Branch of the OWRC.* In addition, data from earlier studies in 1965 and 1967 and a biological study in 1967 were used to complement the findings of the 1971 survey. These studies were requested by the OWRC Divisions of Industrial Wastes and Sanitary Engineering to provide information on the environmental effects of wastewaters as part of their on-going pollution abatement programs in the province.

Following a description of the water pollution problems, the report presents a set of water quality standards which would provide water quality suitable for multiple uses including recreation and the protection of fish and other desirable aquatic life. The control measures necessary for achieving these standards are also discussed.

* *Now Ontario Ministry of the Environment*

CHAPTER 1

SUMMARY AND RECOMMENDATIONS

1. SUMMARY AND RECOMMENDATIONS

1.1 SUMMARY

The water quality of the Spanish River downstream from Espanola to the mouth of the river has been seriously impaired by the wastewater discharges from the Eddy Forest Products Ltd. mill at Espanola and by the effluent from the Town of Espanola primary sewage treatment plant. In general, the industry was by far the greater source of contamination. The most significant impairments included excessive decreases in dissolved oxygen levels due to discharge of oxygen-consuming wastes (BOD_5) combined with the oxygen demand of accumulated fibre deposits along the river bottom, bacterial contamination, adverse effects on the aquatic biota, and serious degradation of the river's aesthetic value particularly its appearance and odour.

The minimum average dissolved oxygen levels dropped to 4.2 mg/l at a distance of approximately 25 miles downstream from the mill outfall. Exposed fibre banks and accumulations of sludge on the river bottom were noted as far as 16 miles downstream from the mill. Resuspended bottom deposits and floating mats of fibrous sludge were observed between Webbwood and Massey. Bacterial contamination in excess of the OWRC criteria for swimming and bathing was found to extend throughout the survey area.

During the 1967 biological study * , the river was found to be devoid of macroinvertebrate life directly downstream from the mill outfall and only pollution-tolerant sludge worms and midge larvae existed in the reach between Espanola and Massey. Downstream from Massey less pollution-tolerant forms began to appear. These findings demonstrate the acute toxicity of the kraft mill wastes on the aquatic life. In addition, serious fish tainting problems resulting in market rejection of fish obtained from adjacent North Channel have also been reported. The tainting problem has also reduced the value of the river for sport fishing.

At the time of the 1971 study,the mill discharged approximately 47,400 lbs of BOD_5/day,which is typical of the average daily waste input during the year 1971. Using a mathematical model which relates dissolved oxygen in the river to

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* *OWRC, Water Quality Evaluation of the Lower Spanish River, 1967.*

oxygen-consuming waste discharges, it was determined that the total loading to the river should be restricted to approximately 12,000 lbs BOD_5/day in order to maintain a minimum dissolved oxygen level of 5.0 mg/l during the summer low flow periods (1,200 cfs, temperature 22°C). To provide for variations in waste treatment efficiency, contingencies such as hazardous material spills, and the possibility of increased demand for wastewater disposal, 33 percent of the total organic loading capacity should be held in reserve. The remaining 67 percent (approximately 8,000 lbs BOD_5/day) would be allocated to the Eddy Forest Products mill and the Town of Espanola. If the oxygen-consuming bottom deposits were removed or if higher summer flows were maintained, the above loading limit could be increased.

1.2 RECOMMENDATIONS

In an effort to alleviate the pollution problems which exist in the Lower Spanish River, it is recommended that:

1. Eddy Forest Products Ltd. continue its pollution abatement programs to:

    a) ultimately reduce the organic wastewater loading from its Espanola Mill to 8,000 lbs BOD_5/day;

    b) eliminate toxic, taste and odour producing contaminants from its mill discharges;

    * c) ensure that the suspended solids level in the mill discharge is maintained consistently below 50 mg/l;

    d) ensure that all sanitary wastes from the mill are segregated from process wastes and discharged to the municipal sewerage system.

2. The Town of Espanola modify its treatment system to provide adequate disinfection of the effluent from its sewage treatment plant on a year-round basis.

3. The Town of Webbwood chlorinate the effluent from the proposed lagoon;

4. A feasibility study be carried out to determine if the summer low flows in the Spanish River at Espanola can be increased.

* *Eddy Forest Products Limited has now installed a mechanical clarifier to treat wastes from the pulping and paper-making processes and two parallel sedimentation lagoons to treat wastes from the woodroom operations. These treatment facilities, in conjunction with in-plant control programs, are expected to maintain the suspended solids level below 50 mg/l in all mill discharges.*

CHAPTER 2

BASIN DESCRIPTION AND WATER USES

2. BASIN DESCRIPTION AND WATER USES

2.1 BASIN DESCRIPTION

The Spanish River drains about 5,400 square miles of the southern half of the District of Sudbury. It flows in a westerly direction through the Town of Espanola to the North Channel (Lake Huron).

Two major tributary streams augment flow in the Spanish River. The Vermilion River joins from the east near Espanola and the Aux Sables River flows in from the north at the Town of Massey. Gough Creek, a third but much smaller tributary, from the northeasterly direction, enters the river approximately one mile west of the Town of Webbwood.

In the survey area downstream from Espanola (shown in Figure 2.1), the stream width varies from about 300 to 400 feet with an average depth of 10 to 15 feet and an average velocity of about 0.8 fps.

The basin is largely cut from sand filled valleys in which banks of the river rise in many areas to 60 feet above the water level. Occasional outcrops of bedrock which occur along the watercourse add to the natural beauty of this river.

Hydrology

Streamflow records have been kept at the hydro electric power generating station operated by the pulp and paper mill at Espanola since 1947. An analysis of these records indicates that while the mean streamflow at Espanola is about 4,500 cfs, summer flows as low as 1,200 cfs can be expected.

2.2 WATER USES

Water Supply

The Spanish River is used as a source of process and drinking water by the Eddy Forest Products Limited pulp and paper plant at Espanola. The drinking water is chlorinated prior to consumption by the mill employees.

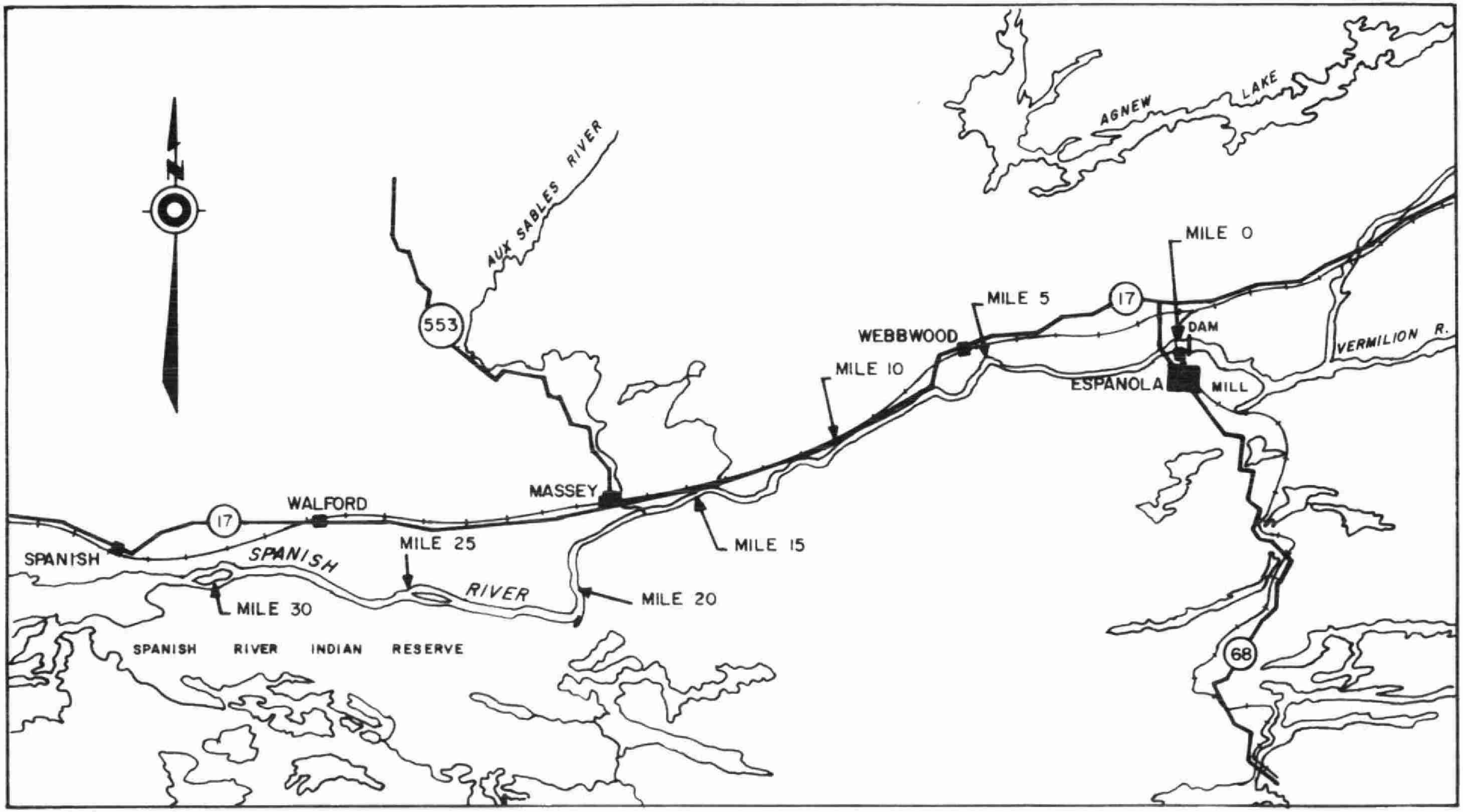

Fig. 2.1 The Lower Spanish River

The Town of Espanola obtains its water from Lake Apsey, the Town of Webbwood from private wells and the Town of Massey from the Aux Sables River. About 40 persons in the settlement of Spanish obtain their water from the Spanish River via a communal water supply system.

Power Generating

Five hydro-electric power generating developments are located in the Spanish River basin upstream from Espanola. Four of these installations are owned and operated by the International Nickel Company of Canada Limited near the community of Nairn about 15 miles east of Espanola. The fifth development, located at Espanola, is owned and operated by Eddy Forest Products Limited.

Recreation

The Spanish River basin,because of its proximity to large growth centres and transportation routes in Northern Ontario complemented by its natural beauty,offers excellent potential for recreational uses. The river is easily navigable from its mouth to the dam at Espanola and would provide a protected inland navigation route for boats and canoes through a very picturesque area of the province. However, at present, very little use is made of the river for recreational uses mainly because of its polluted condition. For example, the peculiar offensive odour of the river water downstream from Espanola and the bacterial contamination throughout the lower reach of the river virtually eliminate swimming and riverside recreation. Furthermore, the objectionable flavour of fish from the river and adjacent portion of North Channel limit the use of the area for sport and commercial fishing. Even the tourist establishments at the community of Spanish direct their sports fishing clientele to the North Channel away from the river mouth.

Waste Disposal

At the time of the 1971 study, all process wastewaters from the Eddy Forest Products Limited mill were discharged through a foam pond as well as two sewers (close to the foam pond) to the Spanish River downstream from the dam at Espanola.

Sanitary wastes were segregated and directed to the Town of Espanola sewage treatment plant (STP). In December 1971, a lagoon system for the treatment of wood room wastes was put into operation. Effluent from this system is discharged to the forebay about one-half mile upstream from the dam.

Domestic wastes from the Town of Espanola (population 5,607)* are directed to the OWRC-operated sewage treatment plant. The unchlorinated effluent from this 0.66 MIGD primary plant is discharged to the Spanish River about one-half mile downstream from the paper mill outfall.

Presently both Massey and Webbwood dispose of their sanitary wastes by individual septic tanks. A provincial project is presently underway to provide a waste stabilization lagoon for the Town of Webbwood with seasonal discharge to the Spanish River.

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* *1971 Municipal Directory, Ontario Department of Municipal Affairs*

CHAPTER 3

SURVEY PROGRAM

3. SURVEY PROGRAM

3.1 MILL SURVEY

An industrial waste survey of the Eddy Forest Products Limited mill at Espanola was conducted from August 23 to 26, 1971. Twelve-hour composite samples were collected from the main mill sewer, kraft mill sewer, sewers 10 and 11 and the foam pond effluent. Samples were analyzed for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pH, and total, suspended and dissolved solids. Sewer flows were obtained from plant records.

3.2 RIVER SURVEY

Water quality surveys of the Spanish River were conducted in the summer of 1965, in September of 1967 and in August of 1971. The survey area is shown on Figure 2.1. During the latest survey, sampling stations were established at a point immediately upstream from the mill and at two to three mile intervals to the mouth of the river about 32 miles downstream. All stations were sampled at approximately 4-hour intervals over a 72-hour period between August 24 and 26, 1971. The samples were shipped immediately after collection to the OWRC laboratories in Toronto where they were analyzed for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), solids, nutrients, colour and bacteria.

During each sampling run dissolved oxygen levels and water temperatures were measured in the field using electronic dissolved oxygen meters. In addition, recording dissolved oxygen meters were installed in the river at three locations (Miles 12, 16, 23) downstream from the mill. *In Situ* measurements using a benthal respirometer (OWRC design) were also conducted to determine the oxygen uptake rates of bottom deposits approximately one-half mile downstream from the mill.

During the biological survey which was performed in 1967, sediment samples were collected to determine the composition and extent of bottom deposits and the number and diversity of bottom fauna.

Since April 1968, water samples have been collected monthly for chemical and bacteriological determinations from two water quality monitoring stations, one at Highway 17 and the other at Webbwood Bridge.

CHAPTER 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 WASTE SOURCES

At the time of the 1971 mill survey, the Eddy Forest Products Limited mill at Espanola discharged approximately 26.6 MIGD of wastewaters to the Spanish River. The wastewater loadings into the river are summarized in Table 4.1. The oxygen-consuming wastes (BOD_5) and suspended solids contained in the mill discharges amounted to approximately 47,400 lbs and 49,600 lbs per day, respectively. These loadings are typical of the average waste inputs from the mill.

The average suspended solids level of 186 mg/l in the mill effluent failed to meet the OWRC objective of 50 mg/l. Although the sanitary wastes from the mill have been separated from process wastes and discharged to the municipal system, fecal coliform levels in the mill effluent were high, suggesting that some sanitary wastes were gaining access to the process waste streams.

Waste treatment controls at the mill during the study were limited to a small foam pond and some in-plant control measures. However, the foam pond was ineffective for suspended solids removal and the wastes were in effect discharged directly to the river.

As mentioned earlier, the wood room wastes were separated in December 1971 from process wastewaters and treated separately in a lagoon which discharges upstream from the dam. The company has now installed a mechanical clarifier to treat wastes from the pulping and paper-making operations. Several in-plant controls have also been introduced. With these control measures, it is expected that suspended solids level in all mill discharges will be within the 50 mg/l objective.

The company has also been asked to investigate biological treatment processes for reducing the organic waste loading by 65 percent.

The primary sewage treatment plant serving the Town of Espanola discharged approximately 0.35 MIGD of effluent containing 480 lbs of BOD_5 per day into the river. This loading is relatively small in comparison to the industrial plant.

TABLE 4.1

SUMMARY OF WASTE INPUT DATA - 1971

PARAMETER		EDDY FOREST PRODUCTS LTD.	ESPANOLA SEWAGE TREATMENT PLANT
BOD_5	lbs/day (mg/l)	47,400 (178 mg/l)	480 (143 mg/l)
Total solids	lbs/day (mg/l)	276,000 (1,040 mg/l)	920 (275 mg/l)
Suspended solids	lbs/day (mg/l)	49,600 (186 mg/l)	167 (50 mg/l)
Total phosphorus	lbs/day (mg/l)	-	34 (10 mg/l)
Total organic nitrogen	lbs/day (mg/l)	-	151 (45 mg/l)
Total coliform* bacteria (range)	per 100 ml	53,500 (10 to 4.6×10^6)	4,250,000 (1.04×10^6 to 17.3×10^6)
Fecal coliform* bacteria (range)	per 100 ml	-	1,110,000 (4×10^5 to 3.1×10^6)
Fecal streptococcus* bacteria (range)	per 100 ml	-	120,000 (7×10^4 to 2.04×10^5)

* geometric mean densities

Note: average mill wastewater flow during survey - 26.6 MIGD
average sewage treatment plant flow during survey - 0.35 MIGD

However, since the effluent is not chlorinated, the bacterial levels in the effluent were very high (Table 4.1) and were the main source of contamination to the river. In an effort to improve the bacteriological quality of the river, improved treatment including disinfection will be required at the municipal treatment plant. Also for long-term protection of the river and ultimately the Great Lakes, consideration should be given to the reduction of nutrient materials discharged from the municipal sewage treatment plant.

4.2 WATER QUALITY

A summary of the water quality data obtained during the 1971 survey data is presented in Table 4.2. Each of the main water quality characteristics is discussed below.

Biochemical Oxygen Demand and Dissolved Oxygen

During the 1971 survey, dissolved oxygen (DO) levels ranged from a maximum of 8.0 mg/l upstream from the mill to a minimum of 3.1 mg/l at 25 miles downstream from the mill. The dissolved oxygen sag curve presented in Figure 4.1 indicated a minimum average concentration of 4.2 mg/l at 25 and 28 miles downstream from the pulp and paper mill. The recording DO meters indicated no significant diurnal-nocturnal fluctuations in dissolved oxygen concentrations in the river. This suggests that at the time of the study, the growths of algae and other aquatic plants were not adversely affecting the oxygen resources of the river.

BOD_5 concentrations averaged 0.8 mg/l upstream from the mill. With the addition of the 47,400 lbs/day BOD_5 from the mill, the average concentration increased to 2.6 mg/l downstream from the mill outfall. The BOD_5 gradually decreased with increasing distance downstream and reached a level of 1.0 mg/l at the mouth of the river. Summaries of BOD_5 levels and residual loadings are presented in Table 4.2 and Figure 4.2, respectively.

Water quality monitoring results from April 1968 to date indicate average dissolved oxygen and BOD_5 levels of 11.3 and 1.4 mg/l, respectively, at Highway 17 Bridge upstream from the mill. Similarly, at Webbwood Bridge, 5 miles downstream from the mill, the monitoring results indicate 10.8 mg/l and 3.8 mg/l of dissolved oxygen and BOD_5, respectively. Data from these two stations are summarized in Table 4.3. Results of samples taken at Mile 4 during the survey indicate average concentrations of 6.5 mg/l dissolved oxygen and 2.6 mg/l BOD_5 (Table 4.2).

TABLE 4.2 SUMMARY OF WATER QUALITY SURVEY DATA, 1971 - LOWER SPANISH RIVER

Station Miles	Dissolved Oxygen Avg. mg/l	Dissolved Oxygen Range mg/l	Dissolved Oxygen No. Samples	BOD_5 Avg. mg/l	BOD_5 Range mg/l	BOD_5 No. Samples	Solids Total mg/l	Solids Suspended mg/l	Solids Dissolved mg/l	Solids No. Samples	COD Avg. mg/l	COD No. Samples
Control												
Mile Ø	7.3	6.5 - 8.0	14	0.8	0.2 - 1.4	9	38	5	33	2	<30	6
Mile 1	7.1	6.3 - 7.9	14	2.3	1.0 - 4.5	9	58	8	50	2	<30	6
4	6.5	5.5 - 7.4	14	2.6	1.2 - 4.0	9	80	8	73	2	<30	6
7	5.8	5.0 - 6.9	14	1.9	1.0 - 3.5	9	80	7	73	2	<30	6
10	5.2	4.7 - 6.2	14	1.9	1.0 - 3.5	9	80	7	73	2	<30	5
12	4.6	4.1 - 4.9	14	1.6	1.2 - 2.5	9	77	7	70	3	<30	3
14	4.4	3.7 - 4.7	14	1.8	1.0 - 3.5	9	62	7	55	3	<30	3
16	4.3	3.4 - 4.7	14	1.6	0.6 - 3.0	9	80	7	73	3	<30	3
Aux Sables R.												
D	8.5	8.2 - 9.2	14	0.6	0.2 - 1.0	9	43	5	38	3	<30	3
18	4.7	4.2 - 5.0	13	1.1	0.8 - 1.8	9	67	5	62	3	<30	3
20	4.5	3.9 - 5.3	13	1.2	0.8 - 1.6	8	85	5	80	2	<30	3
21	4.4	3.8 - 4.8	14	1.3	1.0 - 1.8	8	83	5	78	3	<30	2
23	4.4	3.7 - 4.9	14	1.1	0.8 - 1.8	8	83	5	78	3	<30	2
25	4.2	3.1 - 4.7	14	1.1	0.8 - 1.6	8	113	8	105	3	<30	2
28	4.2	3.1 - 4.8	14	1.1	0.8 - 1.8	8	90	7	83	3	<30	2
32	4.3	3.5 - 5.1	14	1.0	0.8 - 1.8	8	93	8	85	3	<30	2

Station Miles	Bacteriological Enumeration* Total Coliforms /100 ml	Fecal Coliforms /100 ml	Fecal Streptococci /100 ml	No. Samples	Total Phosphorus as P mg/l	Total Kjeldahl Nitrogen as N mg/l	Colour (Hazen Units)	Phenolic ** Substances µg/l	Time of Travel (days) at 2,550 cfs
Control									
Mile Ø	178	4	2	4	.014	.21	26	0	0
Mile 1	13,200	900	13	4	.031	.32	44	-	.005
4	14,700	790	14	4	.022	.28	45	8	.225
7	9,600	890	2	4	.021	.29	43	-	.394
10	8,500	400	3	4	.025	.28	52	-	.609
12	13,000	800	3	4	.021	.33	50	-	.782
14	6,240	490	9	5	.020	.27	47	-	.926
16	4,300	470	5	4	.020	.28	48	6	1.055
Aux Sables R.									
D	320	48	10	4	.009	.16	32	-	1.088
18	1,800	312	1	4	.019	.27	45	4	1.180
20	5,700	396	3	4	.019	.28	48	-	1.312
21	5,700	250	2	4	.020	.28	60	-	1.422
23	4,600	196	2	4	.018	.27	55	-	1.663
25	3,400	203	1	4	.017	.29	60	3	1.888
28	1,500	142	1	4	.019	.28	55	-	2.215
32	950	68	2	4	.017	.26	60	3	2.860

* Geometric Means

** OWRC, Biology Branch, Water Quality Evaluation of the Lower Spanish River, 1967.

TABLE 4.3 SUMMARY OF MONITORING DATA - SPANISH RIVER *

Station	Year	No. Samples	Dissolved Oxygen		BOD_5		Suspended Solids		Total Phosphorus as P		Total Kjeldahl Nitrogen as N		Total Coliforms/100 ml	
			Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range	Median	Range
Highway 17 Bridge (S38.4)	1971	6	13.4	13-14	2.4	0.4-6.5	6	5-10	0.01	0.01-0.02	0.40	0.25-0.52	184	16 - 2,600
	1970	6	13.0	13-13	0.7	0.4-1.0	5	5- 5	0.02	0.01-0.03	0.43	0.21-0.67	36	8 - 5,900
	1969	11	10.6	8-14	1.6	0.4-3.5	5	1-10	0.03	0.01-0.06	0.71	0.30-1.24	96	12 - 1,100
	1968	7	9.2	8-12	0.8	0.5-1.2	5	1-21	0.03	0.01-0.10	0.71	0.18-2.91	44	4 - 160
Webbwood Bridge (S25.8)	1971	6	13.5	13-14	3.0	1.6- 6.0	9	5-15	0.03	0.0 -0.07	0.46	0.21-0.82	7,500	180 - 104,000
	1970	8	10.6	8-14	3.9	1.8- 6.0	5	5-10	0.04	0.01-1.4	0.60	0.21-1.1	454	300 - 7,000
	1969	11	10.3	6-14	3.8	0.6-10.0	8	5-25	0.12	0.02-1.1	1.20	0.61-1.9	1,475	88 - 194,000
	1968	6	9.0	7-11	4.3	2.0-12.0	8	4-19	0.02	0.01-0.05	0.71	0.37-1.1	810	16 - 53,000

* All concentrations reported in mg/l except Coliforms

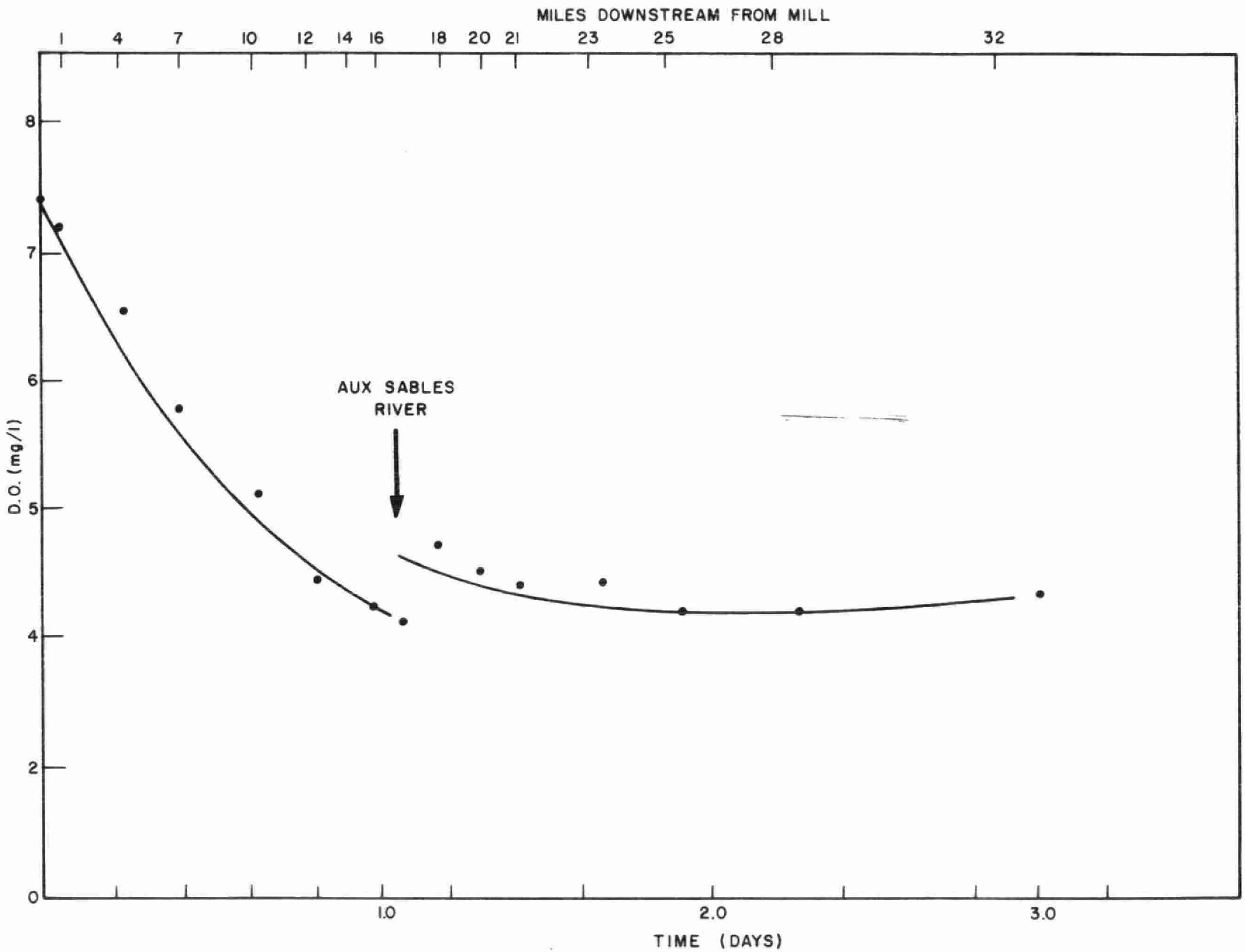

Fig. 4.1 Dissolved oxygen levels vs time - Spanish River

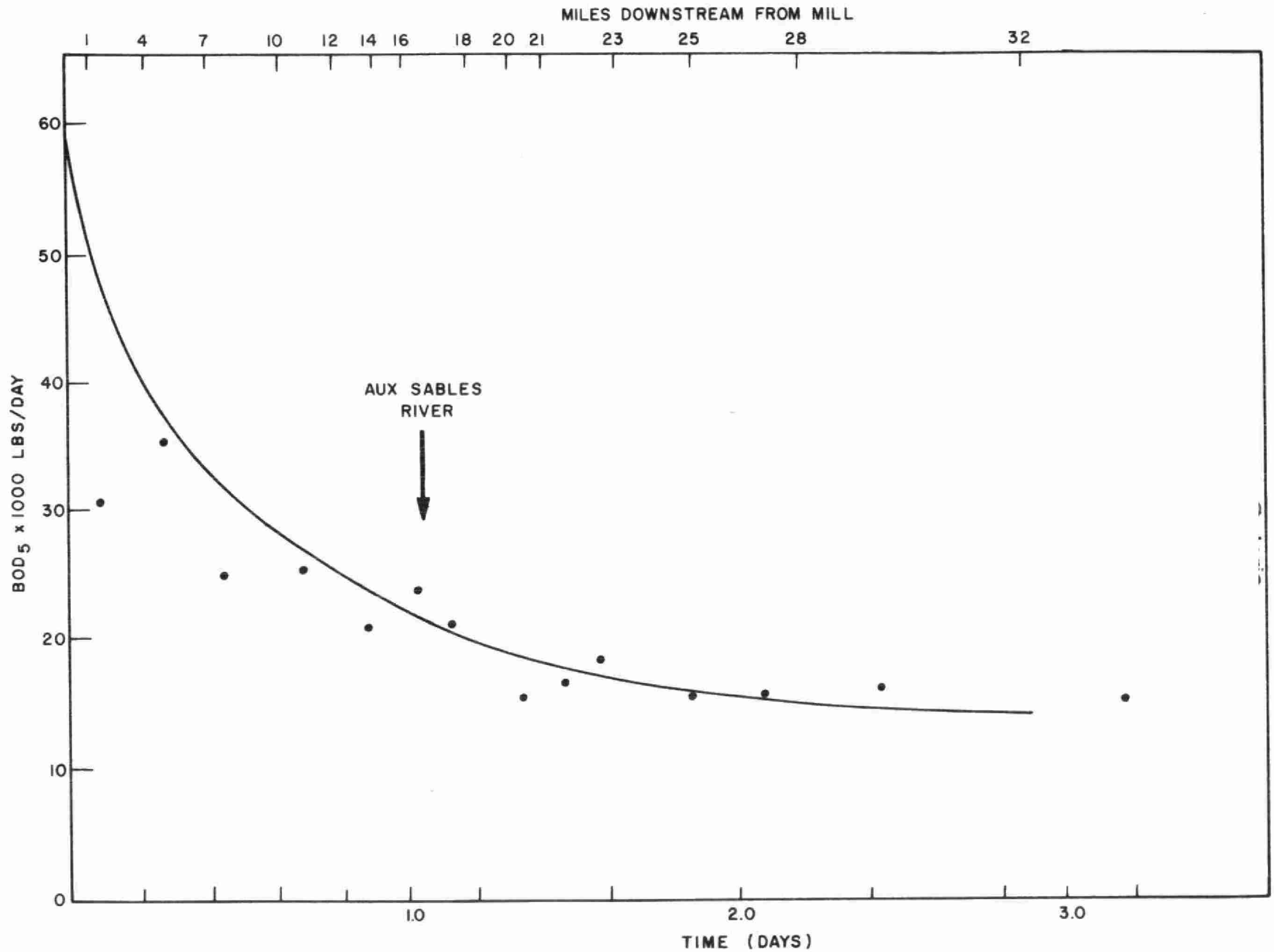

Fig. 4.2 Residual BOD_5 loadings vs time - Spanish River

The higher BOD_5 and dissolved oxygen levels in the monitoring data during the winter months account for the differences in the average values between the survey and monitoring results.

BOD - DO Model

A mathematical model was developed relating deoxygenating waste inputs (BOD_5) and bottom sediments to resulting dissolved oxygen levels in the river. Deoxygenation and reaeration rates were estimated using chemical and physical data collected during the summer. The rates and their definitions are presented in Appendix A.

A benthic oxygen uptake rate of 5.7 grams of oxygen per square meter per day (calculated from *In Situ* oxygen uptake tests during the study) was applied to 20 percent of the streambed over the first sixteen miles of river downstream from the mill. The 20 percent estimate is based on the data shown in Figure 4.2 complemented by data from work carried out in 1971.

A river flow of 1,200 cfs was used as a basis for evaluating the acceptable waste loading to the river. At this flow and allowance for a benthic oxygen demand and a water temperature of 22°C, a value of 11,800 lbs BOD_5 per day was calculated as the assimilative capacity of the river. This load would not reduce the dissolved oxygen in the river below 5 mg/l.

As mentioned earlier, Eddy Forest Products Limited has recently implemented programs to reduce the suspended solids in the mill effluents to 50 mg/l. If this were achieved consistently and the oxygen consumption of the benthic deposits were eliminated, either by physical removal or stabilization with time, the assimilative capacity of the stream could be increased to 14,500 lbs BOD_5 per day at a flow of 1,200 cfs.

The total loading could also be increased with the provision of flow augmentation during the summer drought periods. Figure 4.3 illustrates the assimilative capacity for various flow conditions with and without the effects of the oxygen-consuming bottom deposits.

Under existing conditions with the bottom deposits in place and no flow augmentation, an acceptable waste loading of approximately 8,000 lbs BOD_5/day could be apportioned to the mill and the municipal sewage treatment plant leaving approxi-

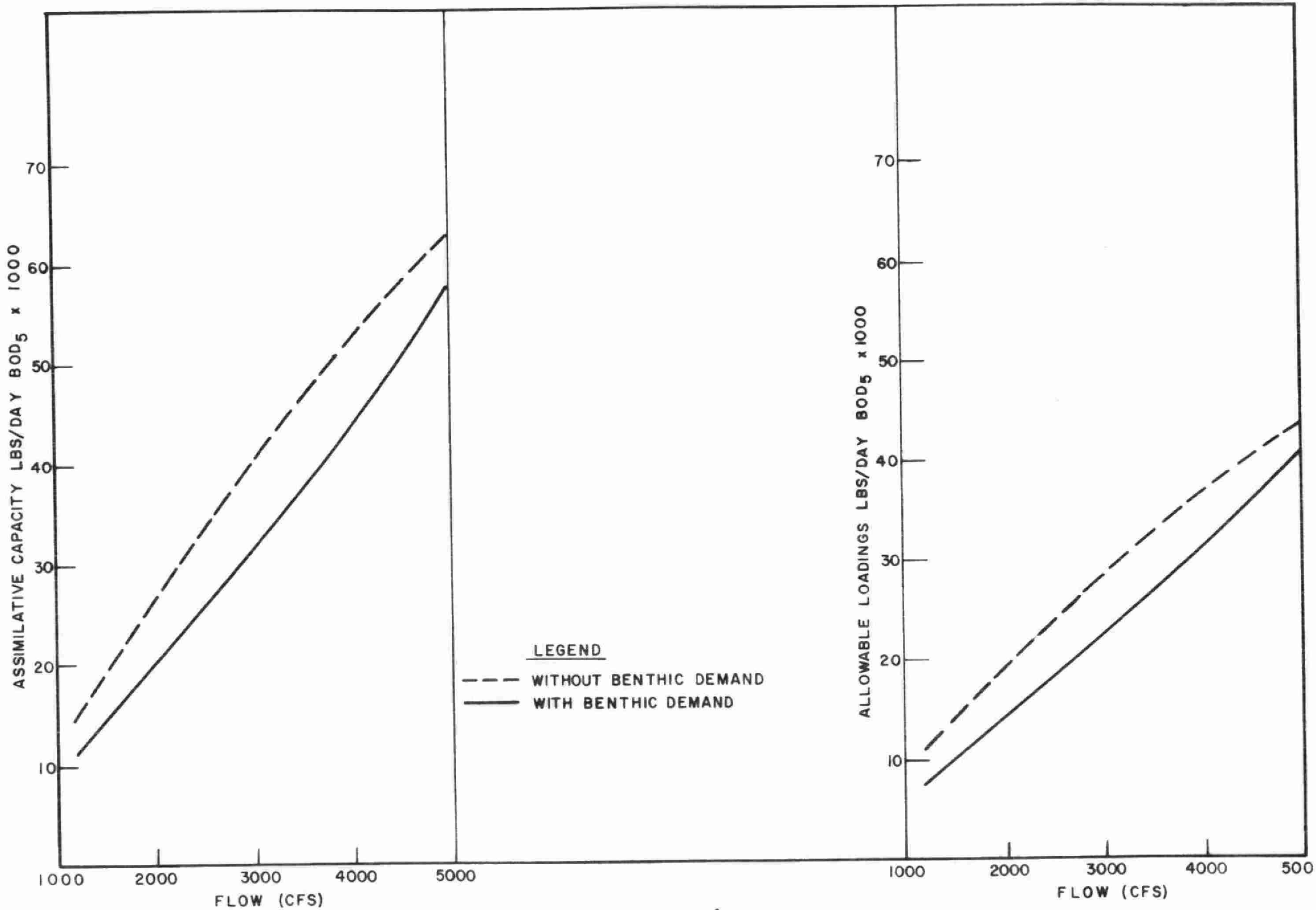

Fig. 4.3 Assimilative capacity vs flow - Spanish River

mately 4,000 lbs/day (33 percent of the total assimilative capacity to be held in reserve) for contingencies and future uses.

Suspended Solids and Bottom Deposits

Upstream from the mill, the suspended solids concentrations averaged 5 mg/l. The mill effluent contained 186 mg/l of suspended solids (average) resulting in downstream concentrations of about 8 mg/l. The concentrations gradually decreased to 5 mg/l at Mile 18 and rose to 8 mg/l at Mile 25 downstream from the mill (Table 4.2). This increase is probably due to the resuspension of decaying bottom deposits buoyed up by the gases of decomposition.

For the first few miles downstream from the mill, fibre banks were exposed along the shoreline. Fibrous deposits were found as far downstream as Massey, a distance of about 17 miles downstream from the mill. Floating fibre mats were also visible in the Webbwood area. During the 1967 biological studies, accumulation of bark and fibre were noted at all dredging locations with the largest concentrations found near the mill and in the slower moving reaches of the river near Mile 13 and the mouth of the river. A classification of the bottom sediments is presented in Figure 4.4.

The oxygen uptake tests of the benthic deposits indicate that the bottom deposits downstream from the mill exerted an oxygen demand of 5.7 $gm/m^2/day$.

Odour

The water in the Spanish River from Espanola to the mouth is malodorous. Results of threshold odour determinations in 1965 and 1967 showed that the odour level was highest directly downstream from the mill with some improvement noted at downstream stations. However, the odour levels increased again at the mouth of the river, probably due to the release of odour-producing components associated with the decomposition of bottom deposits.

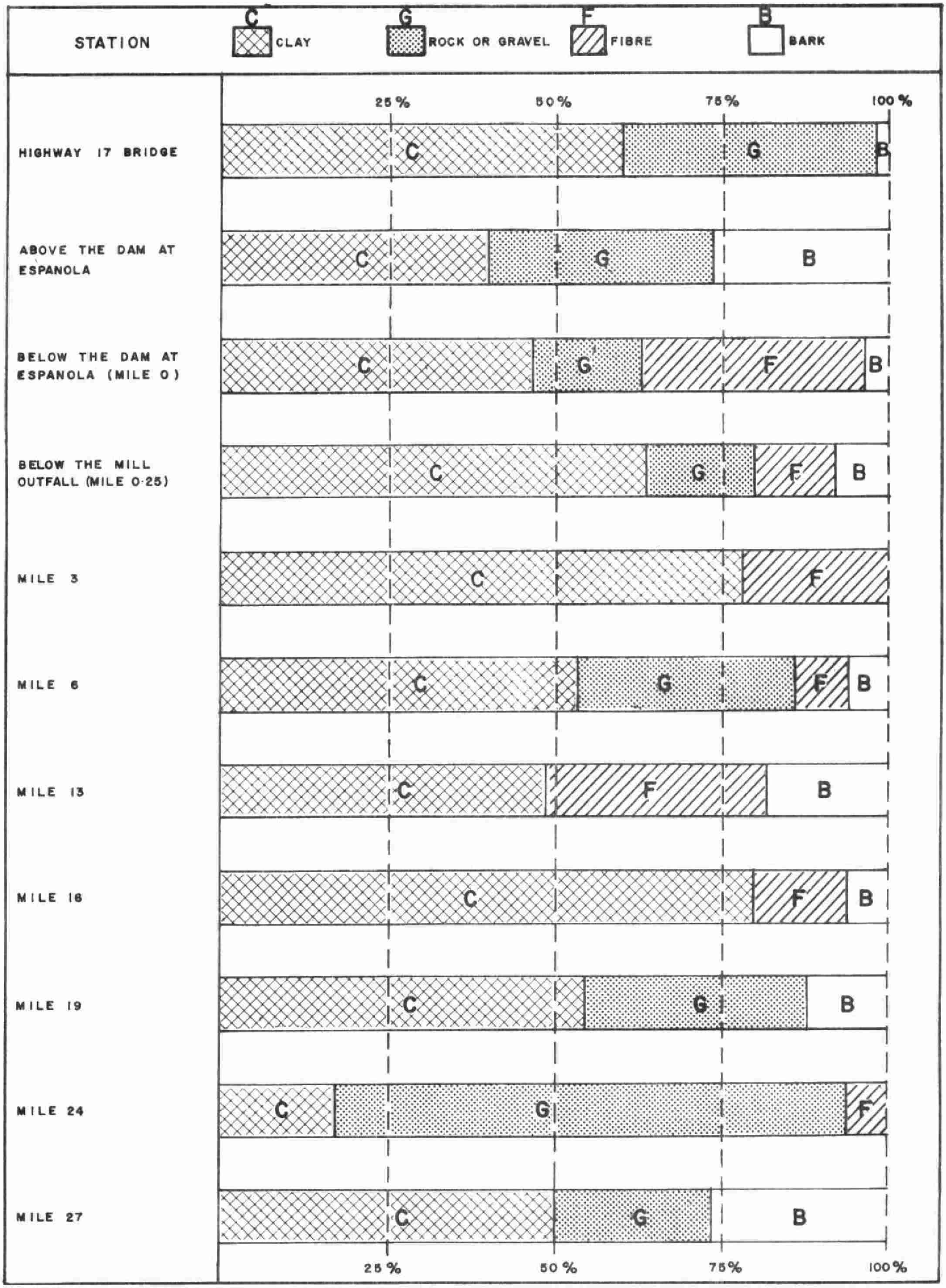

Fig. 4.4 Classification of bottom deposits - Spanish River

Tainting of Fish Flesh

Fish taken from the Spanish River and the adjacent North Channel during the 1965 biological study had an objectionable flavour. Commercial fishermen who fish the North Channel in the vicinity of the mouth of the river have reported that buyers rejected or paid low prices for their catches because the fish were tainted. Complex organic compounds and possibly phenolic substances in the kraft mill wastes are believed to contribute to the objectionable taste. Samples collected in 1967 indicated concentration of phenolic substances of 10 μg/l immediately downstream from the mill. The levels decreased gradually but were still at 3 μg/l near the river's mouth.

Bacteria

The bacteriological criteria used by the Ministry of the Environment for assessing the acceptability of surface waters for specific uses are taken from the OWRC publication "Guidelines and Criteria for Water Quality Management in Ontario". In this publication the criteria for swimming and bathing areas are defined as geometric means based upon at least ten samples per month (including samples collected during weekend periods). The geometric mean levels considered acceptable are 1,000 coliform organisms per 100 ml, 100 fecal coliform organisms per 100 ml, and 20 enterococcus (fecal streptococci) organisms per 100 ml. These levels are presented for comparison with the data collected during the survey. When making this comparison, it must be acknowledged that during the period of the survey, it was not possible to collect sufficient bacteriological samples to meet the geometric mean requirements of the above criteria. However, in the following discussions,comparisons with the criteria provide an indication of the relative magnitude of bacteriological water quality problems.

During the 1971 survey, the total coliform, fecal coliform and fecal streptococci densities (geometric mean) were 178, 4 and 2 organisms per 100 ml, respectively, upstream from the mill. Downstream from the mill and the Espanola sewage treatment plant, total coliform levels ranged from 14,700 organisms per 100 ml at four miles downstream to 950 organisms per 100 ml at 32 miles downstream. The regular monitoring data since April 1968 indicate average total coliform levels of 85 organisms per 100 ml at Highway 17 Bridge which is approximately 7 miles upstream from the mill. The mean total coliform level at the monitoring station at Webbwood Bridge five miles downstream from Espanola was 2,360 organisms per 100 ml.

Contamination by fecal coliform bacteria in excess of the OWRC criteria for swimming and bathing was found to occur downstream from Espanola to the mouth of the river. The fecal coliform densities were approximately 500-900 organisms per 100 ml in the first 16 miles of the river downstream from the Town of Espanola. Farther downstream, the densities ranged from approximately 68 to 400 organisms per 100 ml.

Fecal streptococci counts were approximately 14 organisms per 100 ml in the first 4 miles downstream from the waste source. Farther downstream the levels decreased to less than 10 organisms per 100 ml.

Biological Evaluation

As mentioned earlier, a detailed report on the effects of the waste discharges from the Eddy Forest Products Limited mill on the biological life in the Spanish River downstream from Espanola was published in 1967 by the OWRC. The study showed that the control station at Highway 17, about seven miles upstream from the mill outfall, supported a benthic community indicative of clean water as evidenced by the presence of pollution-sensitive organisms.

Immediately downstream from the mill outfall, the sediments were void of macro-invertebrate life thus indicating the presence of toxic wastes. Although no toxicity tests were conducted with the wastes from the mill during the 1967 biological survey, the survey findings suggested that the mill wastes are toxic to the biota. This was later confirmed by random toxicity tests. One mile downstream, pollution-tolerant sludge worms and midge larvae appeared and predominated until Mile 16, where less pollution-tolerant forms began to re-appear. However, moderate water quality impairment was still indicated 25 miles downstream from the mill.

CHAPTER 5

WATER QUALITY CONTROL

5. WATER QUALITY CONTROL

The water resources of Ontario must meet many needs including public, agricultural and industrial supply, recreation, aesthetic enjoyment and propagation of fish and wildlife. The utilization of waters for assimilation and dilution of wastes must take these uses into consideration and every effort practicable should be made to minimize water use conflicts. Wherever possible, polluted waters should be upgraded to ensure satisfactory supplies for future demands exerted by increasing population and industrial growth, urbanization and technological change. Because of its proximity to the Sudbury area and the Trans-Canada Highway 17, coupled with its physical attractiveness and presence of mineral and forest resources, the Spanish River basin possesses significant potential for future growth and development. A clean aquatic environment is an important criterion in planning for municipal and recreational developments and every effort should therefore be made to alleviate the existing water pollution problems in the Spanish River basin (which were discussed in Chapter 4). Restoration of satisfactory water quality would not only provide a wider range of uses for the enjoyment of the existing population but would also attract new development to the area.

It is expected that substantial improvement in water quality will be achieved now that some control programs have been completed by the industry. The recent program included improvement of in-plant housekeeping, installation of a mechanical clarifier and separation of wood room wastes from other process wastes from the mill (the latter measure was completed in December 1971 and should reduce the rate of solids build-up in the lagoon used for treatment of mill process wastes). Now that the clarifier is in full operation, the suspended solids level in the mill effluent is expected to meet the OWRC objective of 50 mg/l. However, it may take considerable time before the sludge banks and floating mats of sludge due to decaying organic sediment can be cleared.

Additional treatment will be required to eliminate the problems with taste and odour-producing waste components and toxicity of the mill wastes. Likewise, in order to provide a minimum dissolved oxygen level of 5 mg/l in the river under low streamflow conditions, the organic wastewater loading (BOD_5) from the mill will have to be reduced substantially.

TABLE 5.1

PROPOSED WATER QUALITY STANDARDS FOR THE LOWER SPANISH RIVER

The following water quality shall be maintained in the Lower Spanish River:

a) SPECIFIC STANDARDS

PARAMETER	CONCENTRATION
Dissolved oxygen	5.0 mg/l
Turbidity	25 Jackson Turbidity Units
pH	6.0 - 8.5
Phenolic substances	0.001 mg/l

Toxic substances - Toxic substances must not be added to water in concentrations or combinations that are toxic and harmful to human, animal, plant or aquatic life.**

Microbiological*	
Total coliform	1,000/100 ml
Fecal coliform	100/100 ml
Fecal streptococcus	20/100 ml

* These limits for bacteria are expressed as geometric means based on a series of at least 10 samples per month.

** Refer to OWRC Guidelines and Criteria for Water Quality Management in Ontario.

b) GENERAL WATER QUALITY STANDARDS FOR THE LOWER SPANISH RIVER

i) Tainting substances - all materials that impart odour or taste to fish or edible invertebrates shall be excluded from the river at levels determined to produce tainting.

On the basis of the mathematical model which was discussed in the previous chapter and if the 5 mg/l requirement for dissolved oxygen is to be met under low flow conditions, an approximate 80 percent reduction in the organic loading would have to be achieved. A Ministerial Order has been issued to the company requesting submission of plans by July 1972 for a treatment system which would reduce the BOD_5 loading from the mill by 65 percent. The 65 percent reduction is considered to be feasible using available technology at this time. This should be considered as a first stage in the treatment programs aimed at ultimately reducing the BOD_5 loading to 8,000 lbs per day. At the same time, the Town of Espanola should strive to improve its treatment facilities to minimize the discharge of organic and nutrient materials and control the bacteriological contamination of the river. With further advances in technology and continuation of pollution control programs by the industry and the municipality, restoration of satisfactory water quality in the Spanish River is foreseeable.

5.1 PROPOSED WATER QUALITY STANDARDS

The OWRC publication "Guidelines and Criteria for Water Quality Management in Ontario" (1970) presents water quality criteria necessary for various water uses. These guidelines have been used in the preparation of the specific water quality standards (Table 5.1) which are proposed for the Lower Spanish River. If these are met, adequate protection for the desirable uses of the river including protection of fish and aquatic life will be provided. A set of general water quality standards which deal mostly with aesthetic quality of the river are presented in Section b) of Table 5.1.

ii) Taste - all substances that will impart an objectionable taste to the water shall be excluded from the river.

iii) Odour-causing materials that are not readily removable by conventional water treatment consisting of coagulation, flocculation, sedimentation, rapid sand filtration and chlorination shall not be discharged to the river.

iv) Oil, petrochemicals or other immiscible substances that will cause visible films or toxic, noxious, or nuisance conditions shall not be discharged to the river.

v) Nutrients from unnatural sources which will stimulate the overproduction of algae, nuisance vegetation, or offensive slime growths shall not be discharged to the river.

vi) Temperature - the normal daily and seasonal temperature variations that were present before the addition of heat due to other than natural causes shall be maintained.

Heated discharges to the water shall not be permitted unless it is clearly demonstrated that heated effluents will enhance the usefulness of the water resource without endangering the production and optimum maintenance of wildlife, fish and other aquatic species. It shall be the responsibility of the user to provide evidence to support the acceptability of the discharge under these terms.

Heat may not be discharged in the vicinity of spawning areas or where increased temperature might interfere with recognized movement of spawning or migrating fish populations.

vii) Settleable materials - substances shall not be added that will adversely affect the aquatic biota or will create objectionable deposits on the bottom or shore of the river.

viii) Water uses in the Spanish River basin should be controlled to prevent the degradation of existing high quality water through the significant increase in concentration of hardness, chlorides, suspended materials, turbidity and other materials indicative of water quality degradation.

APPENDIX A

APPENDIX A

MODELLING THE DO/BOD RELATIONSHIP IN THE SPANISH RIVER

A-1 MODELLING CONSIDERATION

A river is a complex system composed of interacting physical, chemical and biological forces. The overall system or any of the sub-systems making up the whole, respond to changes in waste input, hydrodynamic and physical conditions. Some of these changes, such as streamflow, are readily observable and are comparatively easy to predict. Other factors such as the oxygen demand of bottom deposits, are just as significant but are much more difficult to measure.

The purpose of a model, either physical or mathematical is to reproduce forces within the system, and, once verified, to predict changes in water quality conditions for any combination of alterations to the various forcing functions mentioned above.

A model of the several forces occurring in a watercourse provides an extremely useful tool for solving immediate pollution problems and for assisting in long-term planning of water use and development within a river basin.

In the Lower Spanish River, one pulp and paper mill and one municipal sewage treatment plant, both at Espanola, discharge oxygen-consuming waste products to the system and these materials significantly deplete the dissolved oxygen resources of the river for many miles downstream from the waste sources. In an effort to determine the organic loading limits that should be placed on each pollution source to maintain the water quality standards for the river, a mathematical model of the dissolved oxygen - biochemical oxygen demand relationship was developed.

In this appendix, the modelling techniques, the evaluation of model parameters and the calculation of allowable loadings are presented.

A-2 DO - BOD MODELLING

A flowing, unpolluted stream has an abundance of dissolved oxygen available for the use of the aquatic community. When unstable organic material from man-made or natural sources is introduced, biochemical oxidation utilizing the oxygen resources of the watercourse proceeds. As the organic loading is increased, greater demands are placed on the stream's oxygen supply and a point is reached where the rate of removal of dissolved oxygen (deoxygenation) is greater than the rate of atmospheric reoxygenation. When this occurs, the oxygen level in the stream begins to decrease and, in the extreme condition, can be completely depleted.

The purpose of DO/BOD modelling is to determine the level of organic loading that can be discharged to a watercourse and yet maintain a pre-determined level of dissolved oxygen.

A modified version of the Streeter-Phelps equation (Manhattan 1968)* relating oxygen utilization to reaeration was employed for determining the river's capacity. This equation is written as follows:

$$D = \frac{k_d \cdot L_o}{k_2 - k_r} \left(e^{-k_r t} - e^{-k_2 t}\right) + D_o e^{-k_2 t} + \frac{S}{k_2} \left(1 - e^{-k_2 t}\right)$$

Where: D_o = dissolved oxygen deficit (pounds per day) at the point of reference [usually the point of waste discharge ($t = 0$)].

D = dissolved oxygen deficit (pounds per day) at any point, time t, from the point of reference.

L_o = ultimate biochemical oxygen demand loading (pounds per day) at the point of reference.

t = time of travel (days).

k_r = the coefficient of BOD removal in the watercourse by physical removal (sedimentation) and volatilization (per day base e).

* *Manhattan, "Stream and Estuarine Analysis", Summer Institute in Water Pollution Control, Manhattan College, New York, 1968.*

k_d = the coefficient of deoxygenation (per day, base e).

k_2 = the coefficient of reoxygenation in the watercourse (per day, base e)

S = the rate of oxygen utilization by benthic deposits.
$S = swv$, where
s = oxygen uptake rate (pounds per sq. ft. day)
w = average width of deposit (feet)
v = average velocity over deposit (ft/day).

Summaries of the data collected for modelling purposes are included below with a description of the parameter calculation used in applying the above equation to the Spanish River.

A-3 FIELD INVESTIGATIONS

A survey designed to provide water quality and physical information necessary for mathematical modelling was conducted during August 1971. Activities included dye and drogue studies for time of travel and velocity, benthic respirometer studies to measure the oxygen demand of the bottom deposits and intensive water quality studies. The intensive studies were conducted over a 72-hour period under relatively low flow conditions from August 24 to 26 when the water temperature was high. All major sources of pollution were discharging at the time of this survey. Summaries of the water quality data collected during the intensive study are tabulated in Appendix I.

A-4 CALCULATION OF MODEL PARAMETERS

a) BOD Removal and Deoxygenation

The coefficients of BOD removal (k_r) and deoxygenation (k_d) are approximated directly from a plot of the BOD_5 data collected

during the intensive studies. The reaction rate is the slope of the line resulting from the plotting of the log of the BOD values versus time of travel.

From the BOD data collected during the survey, it appears that a large portion of the organic loading from the mill is lost in the first 0.15 days time of travel. The loss of BOD is not accompanied by a significant loss of dissolved oxygen. Accumulations of organic sludge deposits were also found in this area. Based on these findings it was assumed that suspended organic (BOD) materials were settling to the streambed. Based on the slope of the BOD measured in this area, a BOD removal rate coefficient (k_r) of 2.5/day was calculated.

Throughout the rest of the survey area, the satisfaction of BOD was attributed primarily to oxidation,and deoxygenation rate coefficients (k_d) were calculated from the BOD data. Table A-1 presents a summary of the BOD removal and deoxygenation rate coefficients.

TABLE A-1

Time of Travel (days)	Mileage (downstream from mill)	k_r	k_d
0.0 - 0.15	0.0 - 2.7	2.5/day @ 19°C	.65/day @ 19°C
0.15 - 1.09	2.7 - 16.5	.65 "	.65 "
1.09 - 1.36	16.5 - 20.5	.65 "	.65 "
1.36 - 2.86	20.5 - 32	.24 "	.24 "

The k_r and k_d rates thus established were employed in the modified Streeter-Phelps equation and, where necessary, were altered to more closely approximate the measured DO profiles.

b) Reoxygenation

Reoxygenation of a body of water occurs principally as a result of contact between the air-water interface. Oxygen diffuses from the atmosphere to the water at a rate determined by the amount of water coming in direct contact with the air. A turbulent stream obviously has a much greater ability for re-

aeration than does a slow or stagnant stream. The coefficient k_2 is determined using a constant diffusivity coefficient (D_1) (ft^2/hr @ 20°C), average stream depth feet (H) and average velocity ft/hr (U) in the equation:

$$\frac{(D_1 . U)}{H^{3/2}}^{1/2} \times 24 = k_2/\text{day} \qquad \text{... (Manhattan, 1968)}$$

In the Spanish River, stream depths averaged about 12 feet and average velocities ranged from .4 to .9 feet per second. These depths and velocities when substituted in the above equation resulted in the reaeration rate coefficients (k_2) tabulated below:

TABLE A-2

Time of Travel (days)	Mileage (downstream from mill)	k_2	Streamflow (cfs)
0.0 - 0.15	0 - 2.7	0.50/day base e	2,550
0.15 - 1.09	2.7 - 16.5	0.30	2,550
1.09 - 1.36	16.5 - 20.5	0.30	2,750
1.36 - 2.86	20.5 - 32	0.10	2,750

c) Initial BOD and DO Loadings

Before a mathematical model can be produced a set of initial conditions must be established. In the case of the DO-BOD model, an initial oxygen deficit (D_o) and organic loading (L_o) are required.

In the Spanish River, the initial deficit (D_o) was calculated using the dissolved oxygen data measured at Station 0 upstream from the mill outfall. The average dissolved oxygen concentration was subtracted from the 100 percent saturation value for the average water temperature (19°C) yielding the DO deficit (D_o). This value was converted to pounds per day [D_o (mg/l) x streamflow (cfs) x 5.4 = D_o (pounds per day)] and substituted in the equation.

The initial loading condition (L_o) was calculated by adding the average upstream BOD_5 concentration (converted to pounds per day) to the BOD_5 loadings calculated for the pulp

and paper mill and municipal STP. BOD_5 values were converted to ultimate BOD before being incorporated in the model.

In the downstream reaches, values of D_o and L_o were computed from the mathematical model. Sources of oxygen and BOD from tributary streams were added at their appropriate locations.

d) Ultimate Biochemical Oxygen Demand

The measure of deoxygenating organic matter is the 5-day biochemical oxygen demand value. This analysis measures the amount of oxygen consumed in an airtight bottle over a 5-day period. It is not a measure of the entire organic loading but simply a convenient measure to be compared with other BOD_5 values.

In the stream, the organic loading obviously does not end after 5 days, therefore, the ultimate BOD concentration is required. This value is determined using a constant "K_1", which is a laboratory measurement of the rate of BOD satisfaction over a long period of time, usually 20-25 days. With the K_1 value known, all BOD_5 concentrations can be converted to ultimate BOD using the function $(1-10^{-K_1 t})^{-1}$ where t equals 5 days (FWPCA, 1966).*

The K_1 rate in the Spanish River downstream from Espanola was found to be 0.05/day (base 10).

e) Benthic Oxygen Demand

Decaying sludge deposits can have a significant demand on the oxygen resources of a watercourse and this sink of oxygen is not measured in BOD samples. It, therefore, must be handled as a separate term in the equation. In many instances, the benthic oxygen demand can be measured directly by finding the dissolved oxygen drop in a known volume of water trapped directly over the deposit, computing the oxygen demand per unit area per unit time and estimating the total area of the sludge deposit.

In the Spanish River, oxygen uptake of the sludge deposits was considered significant throughout the first 16 miles downstream from the mill. Direct measurement of the uptake rate was taken about one-half mile below the mill and

* *Federal Water Pollution Control Association, "Water Quality Studies", U.S. Department of the Interior (FWPCA) Water Pollution Training Activities Text, 1966.*

found to be 0.001175 pounds per square foot-day.

The value "S" employed in the modified Streeter-Phelps equation represents the oxygen uptake rate (pounds per square foot day) multiplied by the average width of the deposit (feet) and the average velocity of the water over the deposit (feet/day).

A-5 FITTING THE MODEL TO THE OBSERVED CURVE

Using the aforementioned rates (k_r, k_d, k_2 and S) and the initial organic loading and dissolved oxygen levels, the oxygen deficit (D) is computed for selected time intervals along the reach under consideration. From these results an oxygen profile is plotted. This curve is then compared to the oxygen profile measured during the field investigation. The closeness of the fit indicates the accuracy of the model.

In the Spanish River, the calculated and observed dissolved oxygen profiles agreed reasonably well indicating that the reaction rates calculated from the river data were reasonably accurate.

A-6 ALLOWABLE LOADING COMPUTATION

Employing the model, maximum expected water temperatures and design low streamflows, organic waste loadings that would result in a minimum dissolved oxygen level of 5 mg/l were estimated.

Streamflow data were obtained from records kept for the federal gauge (2CE-1) located at the Eddy Forest Products Ltd. Dam at Espanola. The period of record for this gauge was 1947 to 1970.

Low streamflows were calculated using the method of ranking 7-day average low flow data and assigning a recurrence interval to each of the low flow events to determine design flow (7-day low flow with a 5 percent chance of occurrence).

The flow thus obtained (1,200 cfs) was applied to the mathematical model.

Deoxygenation, reaeration and sludge demand rate coefficients calculated from the survey data were converted to the design water temperature of 22°C. It was assumed that, with the treatment works required to obtain the organic waste loading limit presented in the report, suspended organic materials would be removed prior to discharge to the river and, therefore, the BOD removal rate k_r was eliminated. These rate coefficients and streamflow were substituted in the mathematical model.

The organic loading calculated from the model under design conditions (elevated water temperature and drought streamflow) represents the maximum biochemical oxygen demand loading that the stream could accept and yet maintain a satisfactory dissolved oxygen level. Of this total BOD_5 loading, a portion was reserved for future development. The remainder was allotted to industries and municipalities discharging to the watercourse.

The deoxygenation rate employed is based on a reaction of the river to extremely high organic loadings. With treatment of the industrial and municipal discharges the nature of the treated waste inputs may be somewhat altered and once in the river organic stabilization may proceed at a rate that differs slightly from the calculated k_d rate employed in the model. Once the initial stages of industrial and municipal waste treatment are completed and the organic loading to the river has been substantially reduced, further surveys to 'fine tune' the model will be required.